THE VISUAL EVOKED CORTICAL POTENTIAL AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: (3) The Response to Pattern and Color

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NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
REPORT NUMBER 778

Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4305.08-3001DAC9.09

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SUMMARY PAGE

THE PROBLEM

To develop an objective test of color vision utilizing the visual evoked cortical response.

FINDINGS

A technique to extract a quantifiable response to pattern from the visual evoked cortical potential has been developed. Evaluation of the technique has shown it to be capable of differentiating between color-normal and color-defective individuals of all types.

APPLICATION

This technique is useful for evaluating color vision whenever an objective measure is required. Examples are situations requiring testing for color defect among possible malingerers or evaluating the effects of drugs on brain functioning.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit M4305.08-3001DAC9. The present report is Number 9 on this work unit. It was submitted for review on 6 March 1974, approved for publication on 19 March 1974 and designated as NavSubMedReschLab Report No. 778.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

ABSTRACT

Previous research has shown that it is possible to isolate a response to pattern from the visual evoked cortical potential. This study investigated the optimum conditions for yielding a pattern response and then applied the pattern response to a test of color vision. The results showed that individuals with normal color vision will give a response to pattern when the pattern is formed of either hue differences or luminance differences. Color defective individuals, however, respond only to luminance differences and not to hue differences that they cannot discriminate. Thus the technique can be used as an objective measure of color vision.

THE VISUAL EVOKED CORTICAL POTENTIAL AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: (3) THE RESPONSE TO PATTERN AND COLOR

INTRODUCTION

The visual evoked response (VER) is being used increasingly to assess brain functioning under abnormal or unusual conditions in order to assure that individuals' health and ability to function adequately are not impaired. For example, VERs are recorded in hyperbaric research under conditions which might induce nitrogen narcosis or oxygen toxicity.[1] Another application of the technique is to evaluate the effects of medication on brain functioning in individuals taking drugs. In fact, it was this application which led to the current study of the VER, since we wanted to employ the technique in an intensive study of the effects of drugs on color vision. Our goal was to use the VER as an objective test of color vision, along with a number of subjective and routine screening tests.

In order to determine whether or not a given drug induces a change in normal brain function, it is essential that standards be established for individuals under normal conditions. Unfortunately, this information is not available in the literature, despite the fact that one of the earliest stimulus properties to be investigated was the effect of color on the evoked response. Differences in waveform of the VER were found among color normal individuals, which were attributed to stimulation by different colors. Since similar differences were not found in color defective individuals, the suggestion was made that the VER could be used to assess color vision.[2]

Although this very useful idea was proposed almost ten years ago, there is today no test available for color vision which employs the VER. There have been a number of suggestions made to explain this failure, ranging from the opinion that all color effects are artifacts,[3] to placing the blame on the variability of the VER, both within and among individuals.[4] While our data clearly support the latter alternative, the large amount of data required to assess color vision by means of routine VERs make it an unacceptable technique for mass testing.

A possible way out of this impasse occurred to us as a result of our work with patterned stimuli. While the responses to physical differences in color are small in the VER, it has been shown by many authors that gross changes in waveform occur when the subject views targets that differ in the amount of pattern.[5] In fact, Carroll White has described a clever technique to isolate the pattern response experimentally. Responses to one stimulus (a pattern) are summated in the computer and those to a second stimulus (a blank field), which differs from the first in that one feature is omitted, are subsequently subtracted. If the two VERs are the same, the result would, of course, be a straight line; remainders can be attributed, with

proper controls, to the presence of the unique feature. In this case, of course, the unique feature is the pattern. [6]

Normally forms or patterns are produced by luminance differences, but it is possible to form patterns with only variations in hue. This is the technique used in pseudo-isochromatic plates, the routine test of color blindness; the patterns are composed of colors the dichromat cannot discriminate and thus he cannot detect the pattern.

The electrophysiological measure of color vision described in this paper is a combination of the principles of pseudo-isochromatic plates and the add/sub technique for pattern response. Patterns are formed from different hues - hues that lie on the confusion lines of deuteranopes or protanopes - and these individuals are tested for a pattern response in the VER. Presumably, if the dichromat sees no difference between two hues, he will see no pattern and have no pattern response in his add/sub.

There are three parts to this investigation. First, optimum conditions, in terms of electrode position and type of pattern, for eliciting a pattern response were determined. Second, the response of color normals to patterns composed of variations in luminance and in hue were measured to show the normal response. Finally, tests are given to a variety of color defective individuals to compare with the normal response.

PROCEDURE

Recording conditions

The recording technique for the visual evoked response is conventional; the electroencephalographic signal is amplified by Grass pre-amplifiers and fed to a Computer of Average Transients. The analysis interval is one second; 100 intervals are summed for each VER.

Both monopolar and bipolar recordings were made. For the monopolar, the active electrode was placed 2 cm above the inion on the midline; the right ear was the reference and the left ear the ground. Bipolar recording utilized electrodes 2 and 7 cm above the inion with the left ear as ground.

Experimental technique

Since our interest was in isolating a response to a pattern, all data were collected by summing 100 responses to a form (or blank field) and subsequently subtracting 100 responses to a blank field (or form). Before the subtraction phase, the original VER (the 100 summated responses) was written out. In addition, a VER to the alternate form or blank was obtained so that each set of data consisted of two complete VERs and the results of subtracting one from the other.

This "add/sub technique" is illustrated in Fig. 1. On the left are the normal VERs for two subjects determined for a gray blank field and a field composed of gray checks on a gray background. The two VERs

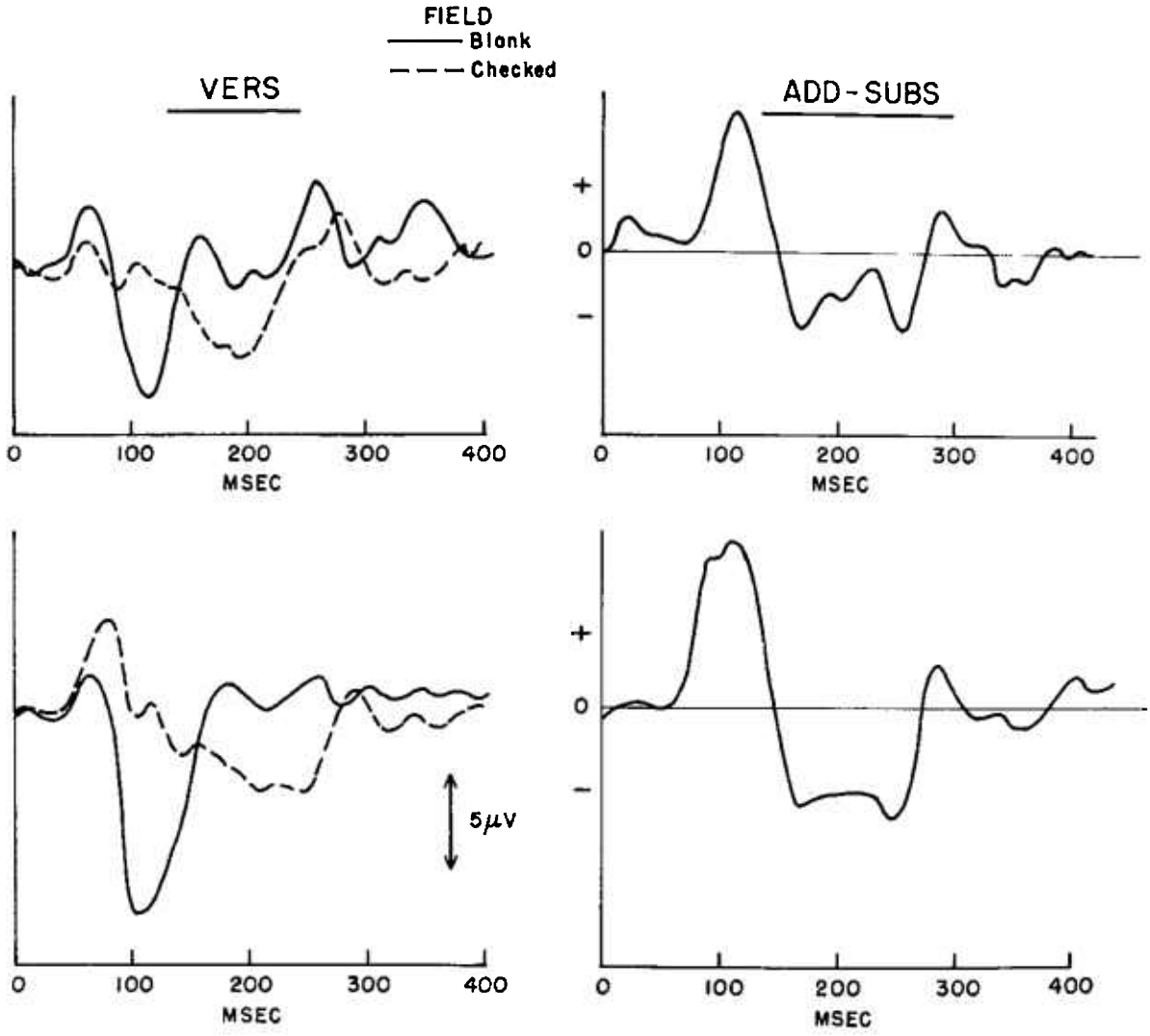


Fig. 1. Illustration of the technique for obtaining a pattern response. Routine VERs for a blank field and a checked field for two subjects are on the left. The results of the computer subtraction for these data, the "add/subs", are on the right.

differ: the curve for the checked field is higher around 100 msec and lower around 200 msec than the curve for the blank field. If the blank-field VER was subtracted from the checked-field VER, one would predict a peak of positive activity around 100 msec and a dip at 200 msec. This is of course what the add/sub technique gives; the result is shown on that right and will hence-forth be called the pattern response.

All orders of presentation were counterbalanced; that is, one half the subjects received the form first and the other half the blank field.

Visual targets

All visual stimuli consisted of pairs of targets, one a blank field of color and the other a pattern superimposed upon the blank-field background. The targets all subtended an angle of 10 degrees on a side, at a viewing distance of four feet. They were constructed of colored papers and illuminated by light from a Grass photostimulator.

Two patterns were investigated in order to determine the optimum pattern for the add/sub technique. These were checks and stripes, both formed of high contrast black and white elements 30 minutes in diameter (1 c/d). Since the checks proved more effective than the stripes, the rest of the patterns were formed of 30 min checks.

For the patterns formed of luminance differences, three different degrees of contrast* were used. Targets were formed of black and white (90% contrast), a light gray on a dark gray (54% contrast), and a light gray on a medium gray (20% contrast).

The targets formed of hue differences were designed specifically for protanopes, deuteranopes and tritanopes. Thus, for example, the deuteranopic set of targets consisted of a blank field of purple and a checked pattern formed from purple and blue hues. The purple and blue were of the same luminance and lie on the confusion lines of deuteranopes. To a color normal person the target appears as a checked field with medium color contrast and no brightness contrast.

The protanope's targets consisted of a blank field of green and a checked field composed of orange and green. To a color normal, the checked field has a slight brightness contrast (7%). This was done purposely to equate the two hues in brightness for the protanope since these color defective individuals have a sizable luminosity loss in the long wavelengths.

The tritanope's targets were formed of checks of pale violet and yellow-green, compared to a blank field of violet. All were of the same luminance.

The pairs of colors used to form each of the checked targets are illustrated in the CIE diagram of Fig. 2. Each lies on a confusion line of the respective color defective individual and presumably the hue cannot be differentiated by him. To the color normal subject, the different hued checks are clearly discernible, but the three sets vary greatly in the amount of hue contrast, with the tritanope's target appearing to have the least and the protanope's an extreme amount. Some normals even report the latter to scintilate under the strobe light, due to the extreme contrast.

Contrast is best defined for stripes or checks by

$$\frac{L_L - L_D}{L_L + L_D}$$

where L_L is luminance of lighter and L_D is luminance of darker.

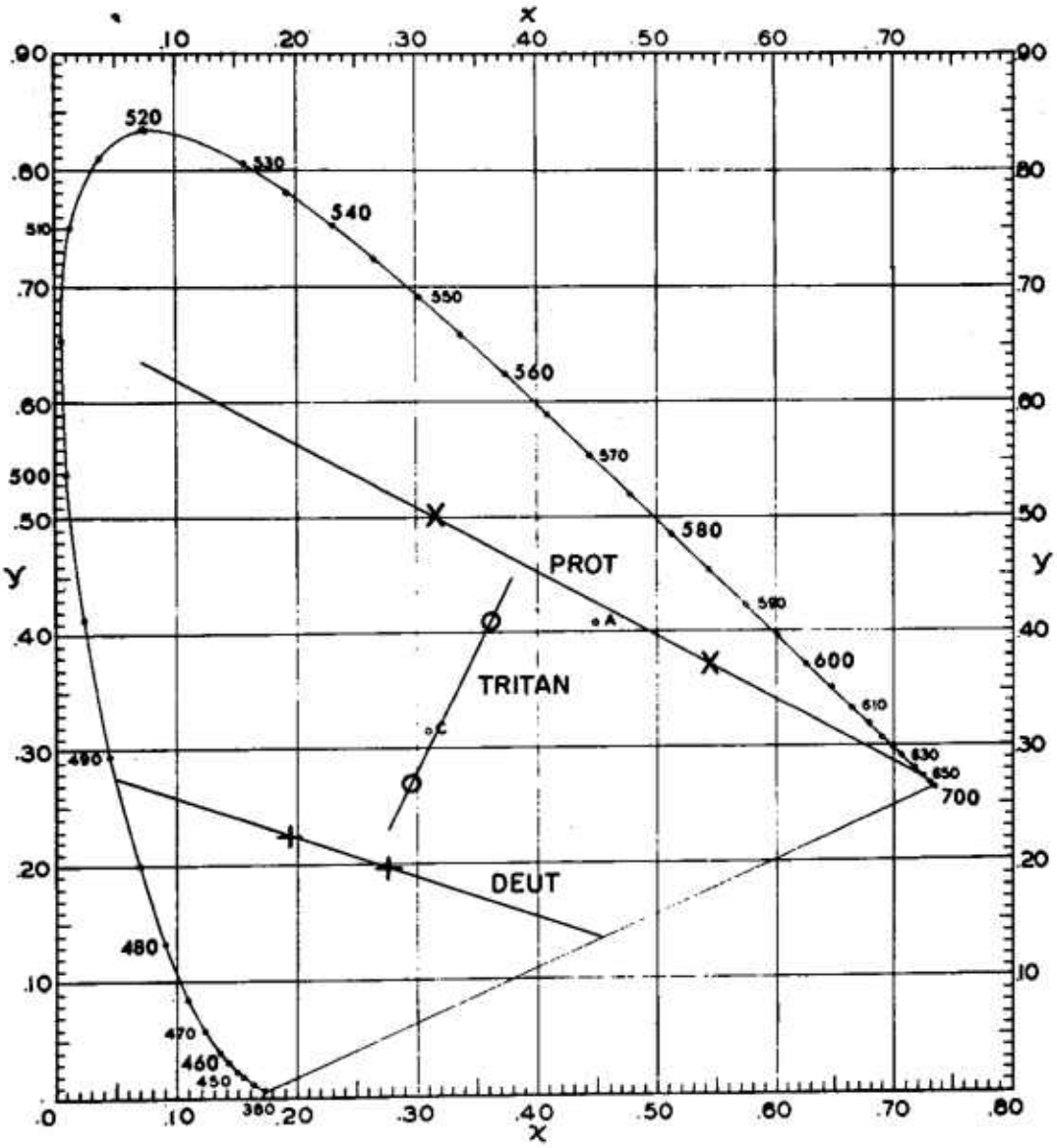


Fig. 2. CIE chromaticity diagram of the colors used to construct the patterns for dichromatic subjects. Each set lies on a confusion line of a deuteranope, a protanope, or a tritanope.

The choice of the color for the blank field is arbitrary, but immaterial, since the differences in VERs to blank fields of color are so small compared to the VER for pattern.

The luminance contrast targets formed of the different grays were selected to look similar, subjectively (for color normals), to the hue targets. Thus the 20% luminance contrast appears similar to the deuteranope's hue target and the 54% contrast target is comparable to the protanope's orange/green hue target. This was done so that the dichromat could be tested on a luminance target that should give a comparable response to the hue target.

Subjects

Subjects for the determination of the optimum conditions for eliciting the pattern response were eight color normals. Data were recorded from all eight for both electrode positions and for both stripes and checks. A second group of eight color normals was employed for all of the targets composed of checks of different luminance and of different hues. For the tests of defective color vision, groups of eight protanopes, eight deuteranopes, eight different color normals, and one tritanope were measured.

The color defective subjects were all measured on the standard NSMRL battery of tests [7] (American Optical Pseudo-Isochromatic Plates, Farnsworth Lantern, the Dichotomous-15, the H-16, and the Hecht-Shlaer Anomaloscope) and judged to be completely dichromatic.

RESULTS

The Effect of Pattern

A complete set of data for two subjects is shown in Fig. 3; this includes VERs determined for a blank field and for patterns formed of stripes and checks under both monopolar and bipolar recording. There are large differences among all the conditions for each of the subjects, but there are also large differences between the subjects in how they respond to the different stimulus parameters. These complex data can be contrasted with the simplified results of the add/sub technique in Fig. 4 for the same two subjects. The pattern response of both subjects is similar, the major feature being a large positive deflection at 90 to 100 msec. This pattern response is larger for the checks than for the stripes for both of the subjects.

The pattern response is consistent among subjects and thus, it is possible to average the responses in terms of amplitude and latency of the various components. These results are tabulated in Table I which gives the mean and standard deviation of each of the components averaged for the eight subjects. The data are plotted in Fig. 5 where the mean pattern response for checks is compared with that for stripes; the amplitude of the response to checks is again larger than that for stripes for both electrode positions.

The data have been replotted in Fig. 6 to show the effect of electrode position on the pattern response. Both monopolar and bipolar recordings yield

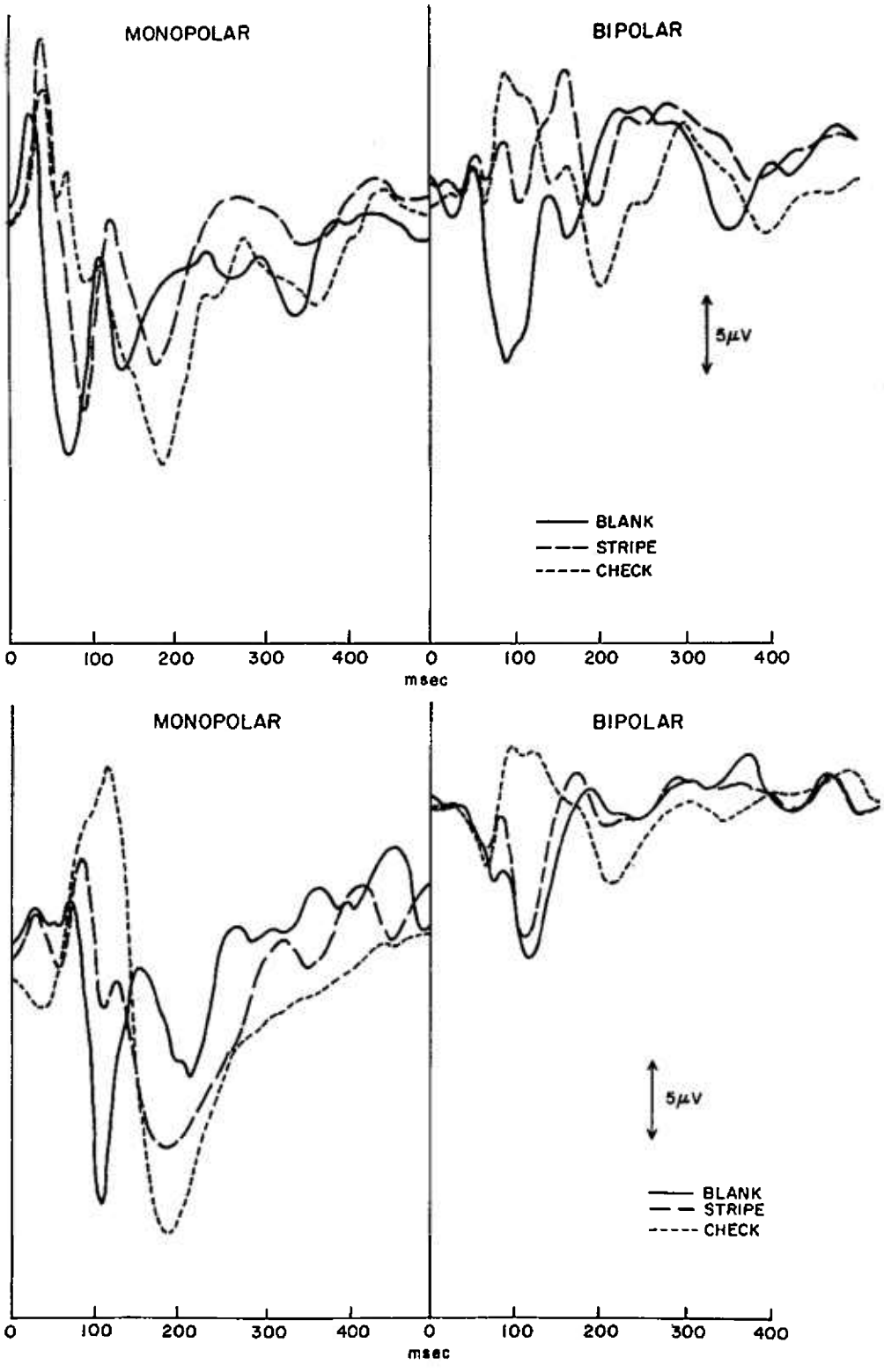
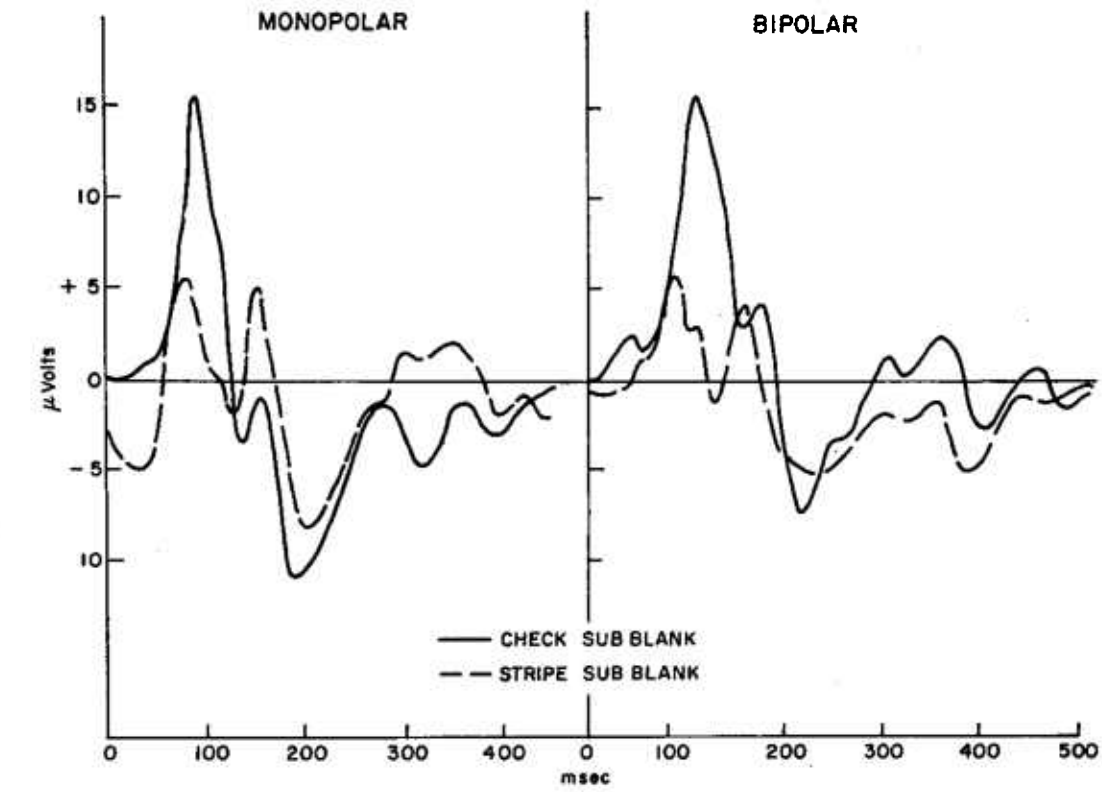


Fig. 3. Routine VERs for blank, striped, and checked fields for two subjects under monopolar and bipolar recording conditions.



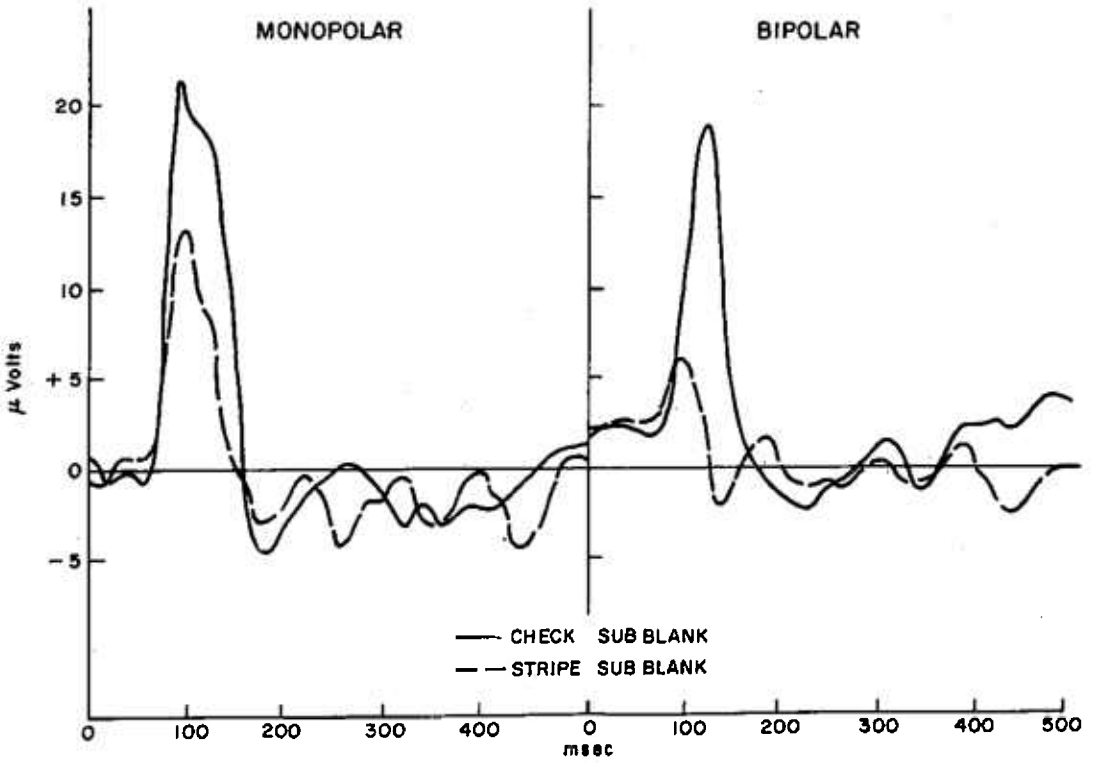


Fig. 4. The results of the "add/sub" technique for the same conditions as Fig. 3.

Table I. Components of add/sub responses. Means and standard deviations for 8 normals

Component	Check Sub Blank		Stripe Sub Blank	
	Monopolar	Bipolar	Monopolar	Bipolar
LATENCIES IN MSEC				
A	55.3 ±13.8	54.5 ±12.2	49.6 ±10.7	54.8 ±10.3
B	98.1 ±12.8	99.0 ± 8.5	88.6 ± 8.8	94.0 ± 8.3
C	162.4 ±17.0	156.2 ±14.7	156.6 ±22.8	154.1 ±23.7
D	196.6 ±29.3	190.9 ±24.4	190.5 ±24.0	193.8 ±30.0
E	232.3 ±19.7	231.6 ±13.4	229.1 ±17.2	231.8 ±22.6
F	287.8 ±15.4	288.4 ±10.5	280.8 ±23.5	284.5 ±20.3
AMPLITUDES IN μVOLTS				
A	-1.61 ± 2.8	-1.09 ± 1.3	-1.99 ± 1.7	-1.41 ± 1.2
B	+9.67 ± 2.7	+11.34 ± 5.7	+6.11 ± 2.0	+4.35 ± 1.7
C	-7.29 ± 5.8	-4.53 ± 5.5	-3.57 ± 1.2	-2.60 ± 3.3
D	-2.02 ± 1.7	-0.22 ± 2.3	+0.29 ± 0.5	+1.49 ± 2.6
E	-5.83 ± 4.9	-3.72 ± 2.3	-3.77 ± 1.8	-2.59 ± 2.5
F	+1.58 ± 3.5	+1.74 ± 2.6	+0.08 ± 2.0	+1.41 ± 2.5

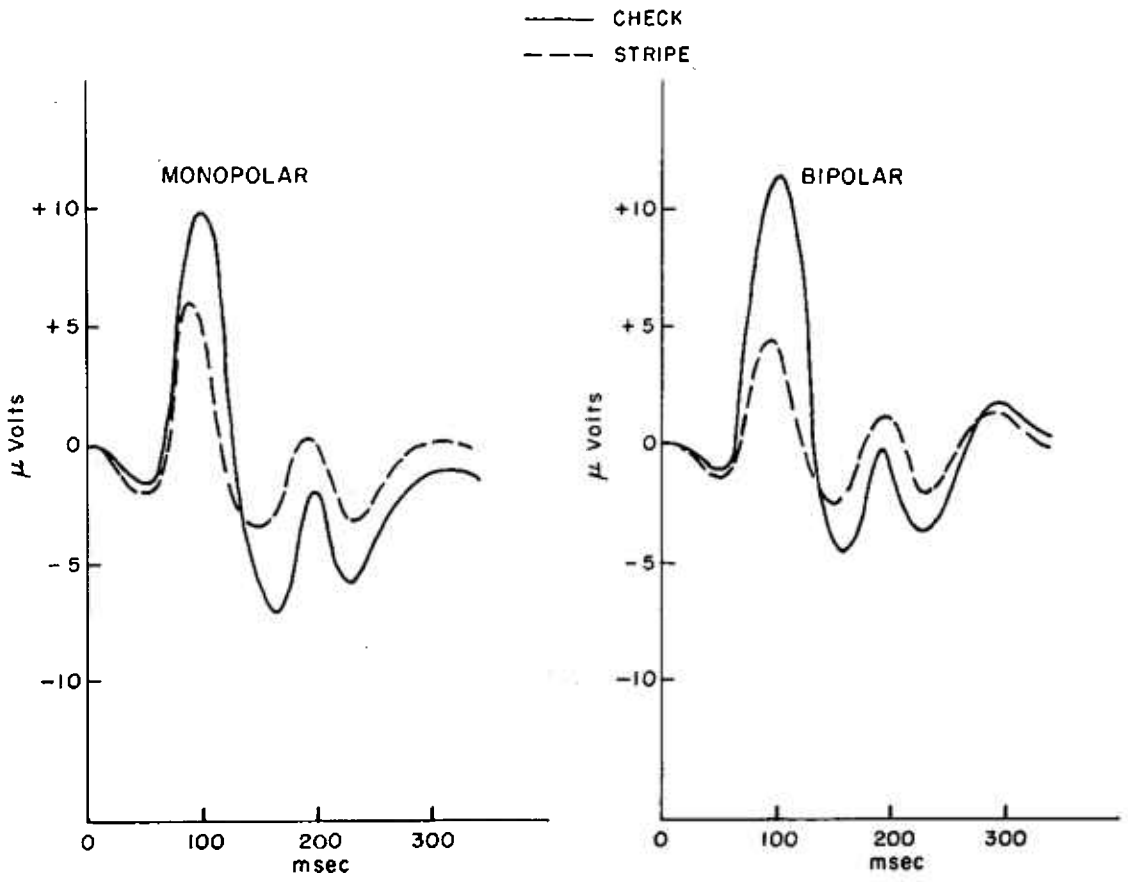


Fig. 5. Comparison of the average pattern response for checks and stripes for eight color normal subjects.

essentially the same pattern response. Analysis of variance was performed on the data for each of the components in terms of both amplitude and latency. For latency there were no significant differences among any of the conditions. For amplitude, the component at about 100 msec was significantly greater for checks than for stripes ($F = 33.0$, 1 and 7 df, $p < .01$) but did not differ for the two electrode positions.

On the basis of these data the experimental conditions for the other investigations were selected. Since the checked pattern proved more powerful in eliciting the pattern response, all the rest of the visual targets were formed of checks. Since the electrode position did not matter, the bipolar condition was chosen because it is less effected by movement artifacts.

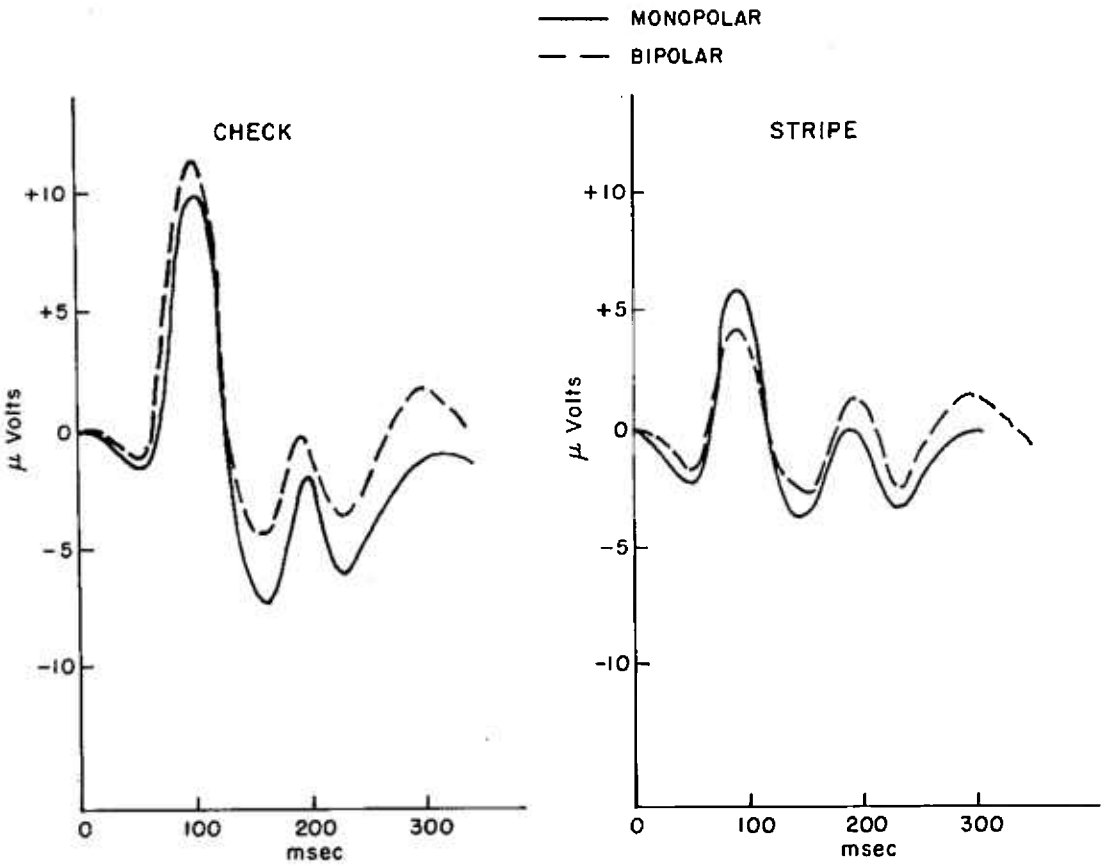


Fig. 6. Comparison of the average pattern response for monopolar and bipolar recording conditions for eight color normal subjects.

The Effect of Luminance Contrast and Hue Contrast on Color Normals

The pattern responses to the luminance contrast targets for the color normal subjects are shown in Fig. 7. Each curve represents the average for the same eight color normal subjects. When responses to a blank field are subtracted from those to a checked field, there is a sizeable peak remaining around 100 msec and a dip around 200 msec. As contrast is reduced two changes occur: the amplitude of the first peak is lowered dramatically and the latencies of the major pattern responses are all increased. The major positive peak, for example, changes from 100 msec, to 108, and finally to 142 msec.

Figure 8 gives the pattern responses of the same eight normal subjects on the targets composed of hue differences;

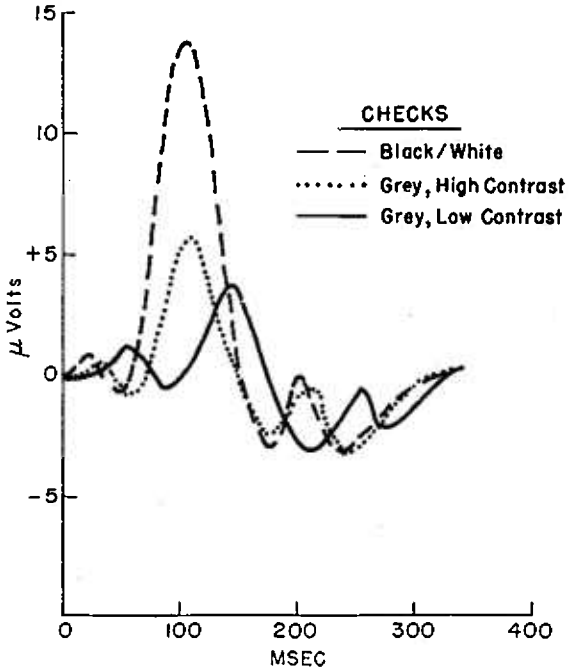


Fig. 7. The average pattern response for the same eight color normal subjects on luminance contrast targets.

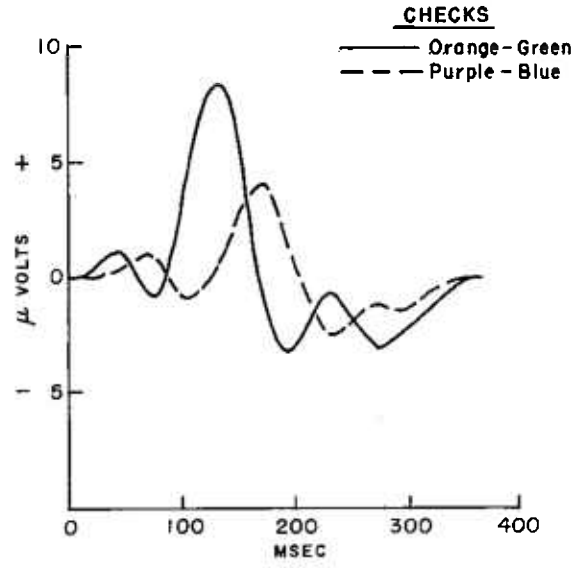


Fig. 8. The average pattern response for the same eight color normal subjects on hue contrast targets.

the same types of phenomena occur as were evidenced in the luminance contrast data. Normal subjects give pattern responses when the pattern is composed of hue differences only; furthermore, these pattern responses to hue behave similarly to those for brightness; that is, the amplitude is reduced and the latencies increase as hue contrast is reduced. Interestingly, the latencies of the pattern response to hue are longer than the pattern response to luminance.

Pattern Responses of Deuteranopes

Preliminary recordings showed that the color defective individuals gave no real pattern response to checks composed of hues they confuse. Since it was, therefore, difficult to quantify their data, an experiment was designed which would yield definitive results. Pattern responses were recorded from eight deuteranopes and a second group of eight color-normals. Amplitudes of pattern responses to hue were then measured at the mean latencies evidenced by the original group of color normals. In order for this procedure to be legitimate, it is, of course, necessary to show that it will discriminate between color normals and color defectives; this is the reason for the second group of color normals.

Figure 9 shows the mean data for the two groups of color normals on the hue pattern. The pattern response for both is essentially the same; there are no significant differences between the groups in latency or amplitude.

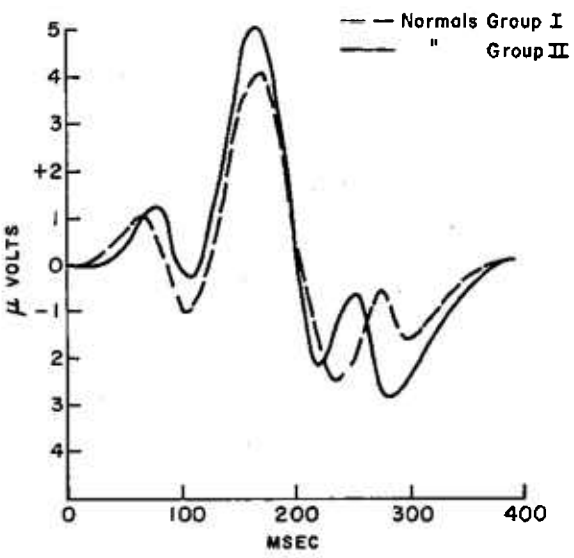


Fig. 9. Average pattern response of two groups of eight color normals on the purple-blue, deuteranopic target.

The results of the amplitude measures for the normal and deuteranopic group of subjects on the deuteranope's targets are given in Table II. Measures were made at 168 and 232 msec, the mean latencies of the two major components of the pattern response for the first group of color normals. Normal Group II again shows the same response as Group I. On the other hand, the deuteranopic data are entirely different, with no evidence of peaks in these locations. It can clearly be stated that these deuteranopic subjects show no pattern response to differences in hue that lie in their confusion zones.

Figure 10 is the data for the neutral target for the three groups; for luminance contrast, the deuteranopic

Table II. Amplitude of Add/Sub Components (μvolts)

Subjects	Latency		Difference
	168 msec	232 msec	1st - 2nd
Normal Group I	+4.10	-2.46	6.56 μv
Normal Group II	+3.86	-2.73	6.59 μv
Deuteranopes	-0.65	-0.25	-0.40 μv
Values of t Gr. I larger than Deuts	4.23	2.15	6.58
Probability	<.01	<.05	<.01

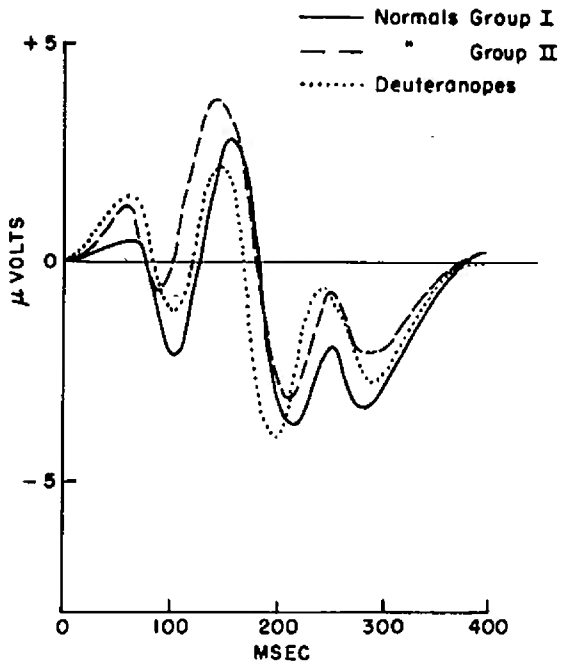


Fig. 10. Average pattern response to low contrast luminance target for three groups of subjects, two color normal and one deuteranopic.

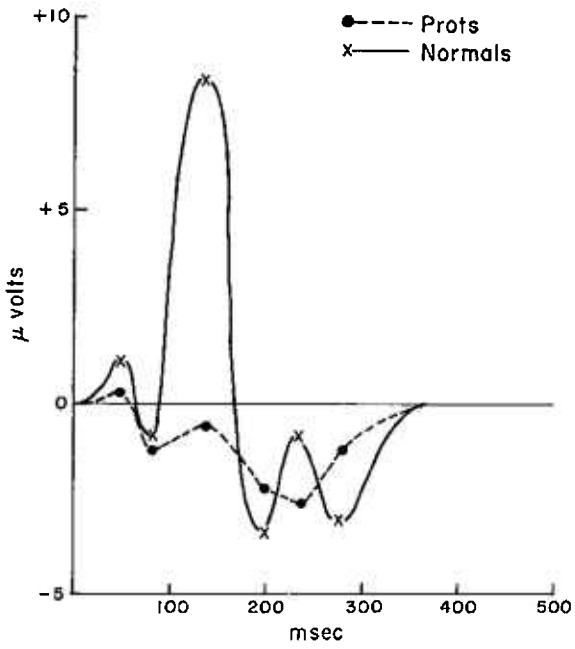


Fig. 11. Average pattern response of color normal and protanopic subjects on the orange-green, protanopic target.

subjects do behave normally. The curves for all three groups are essentially the same and there are no statistically significant differences among them.

Pattern Responses of Protanopes

The comparison of the pattern response of the protanopic subjects with that of the color-normals is shown in Fig. 11 and Table III; these add/sub responses were determined with the orange-green pattern constructed from protanopic confusions. The average response of normal subjects is very large: over 8 μvolts at 135 msec, while the average protanopic add/sub shows no indication of a pattern response.

On the other hand, the protanopes do respond to luminance contrast. Figure 12 compares the protanopes and the color normals on the medium contrast target. Both groups show a large pattern response, with a major positive peak at about 110 msec. There are no significant differences between these curves.

The data shown thus far are the average responses of eight subjects and there were larger individual differences among the protanopes than among the deuteranopes. One subject did in fact show a distinct pattern response when tested on the orange-green pattern; these data are shown in Fig. 13. It should be noted that the pattern responses to hue and to

Table III. Amplitude of Add/Sub Components (μvolts)

Subjects	Latency		Difference 1st - 2nd
	130 msec	194 msec	
Normal Group I	+8.33	-3.33	11.66 μv
Protanopes	-0.65	-2.01	1.36 μv
Values of t GR I larger than Prots	5.62	1.27	4.57
Probability	<.01	-	<.01

luminance are almost identical; this strongly suggests that the two hues were not equated for luminance for this subject and that the apparent hue pattern response was in fact a luminance contrast response.

Pattern Response of a Tritanope

Since tritanopia is such a rare type of color defect, the original experimental design did not include such individuals. However, when a tritanope did become available, it was decided to try the method on him. Figure 14 shows the pattern response for two color normal subjects and for the tritanope for a checked pattern composed of hues from tritanopes' confusion lines. The tritanope has no pattern response while the two color normals have a large positive component around 190 msec. The latter is a much longer latency than the other pattern responses for hue, but it is apparently a manifestation of the minimum contrast. Both color normal subjects were in the original group of eight and show normal latencies for the protanopic and deuteranopic targets.

DISCUSSION

Color-normals, deuteranopes, protanopes, and one tritanope have been tested for a pattern response in the visual evoked response using targets formed of luminance differences and of hue differences. While color normals will give pattern responses for both stimulus parameters, color defectives show a response only to luminance and have no pattern response to hues they confuse. These results indicate clearly that the technique can be used to detect color defects. Since it requires no verbal response from the subject, it can be used with adult malingerers, with children and with animals. The latter should be a very interesting application since rhesus monkeys are now

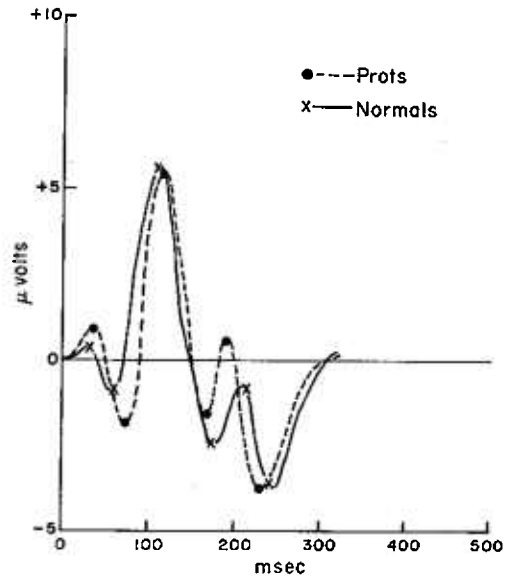


Fig. 12. Average pattern response of color normal and protanopic subjects on the medium contrast luminance target.

so widely used in physiological investigations of color vision.[8]

On the other hand, there is a danger inherent in the use of the technique; that is, confusing a pattern response elicited by luminance with one elicited by hue. This is probably most likely for protanopic subjects, with their large luminosity loss in the long wavelengths. Anomaloscope settings for brightness for these individuals vary widely, indicating that the extent of the loss must be variable.

There are two possible solutions to the problem. First is the one illustrated in Fig. 13. Since the color normal's response to hue and to luminance contrast can be determined, one can predict from the latency of the response

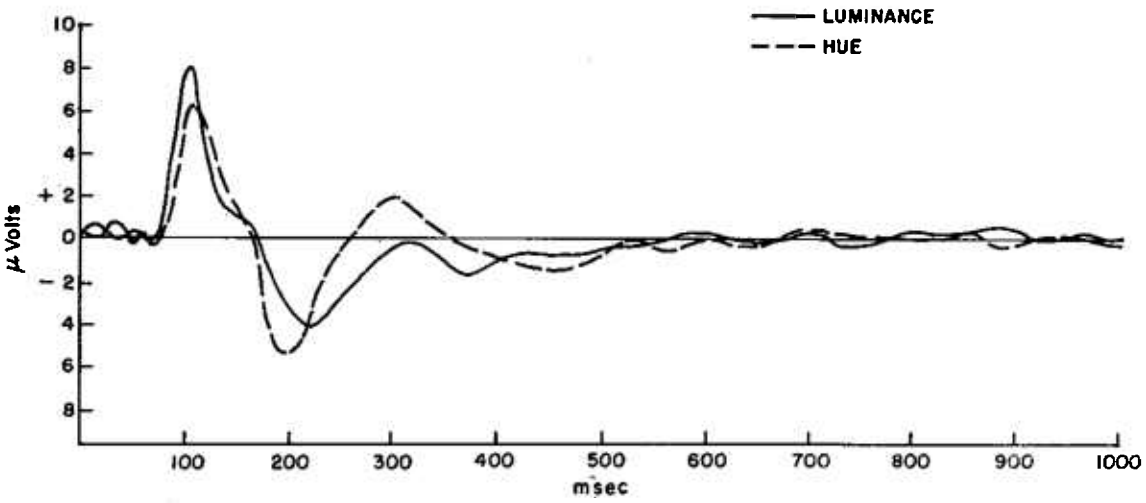


Fig. 13. Pattern responses of one unusual protanope to the hue and luminance targets.

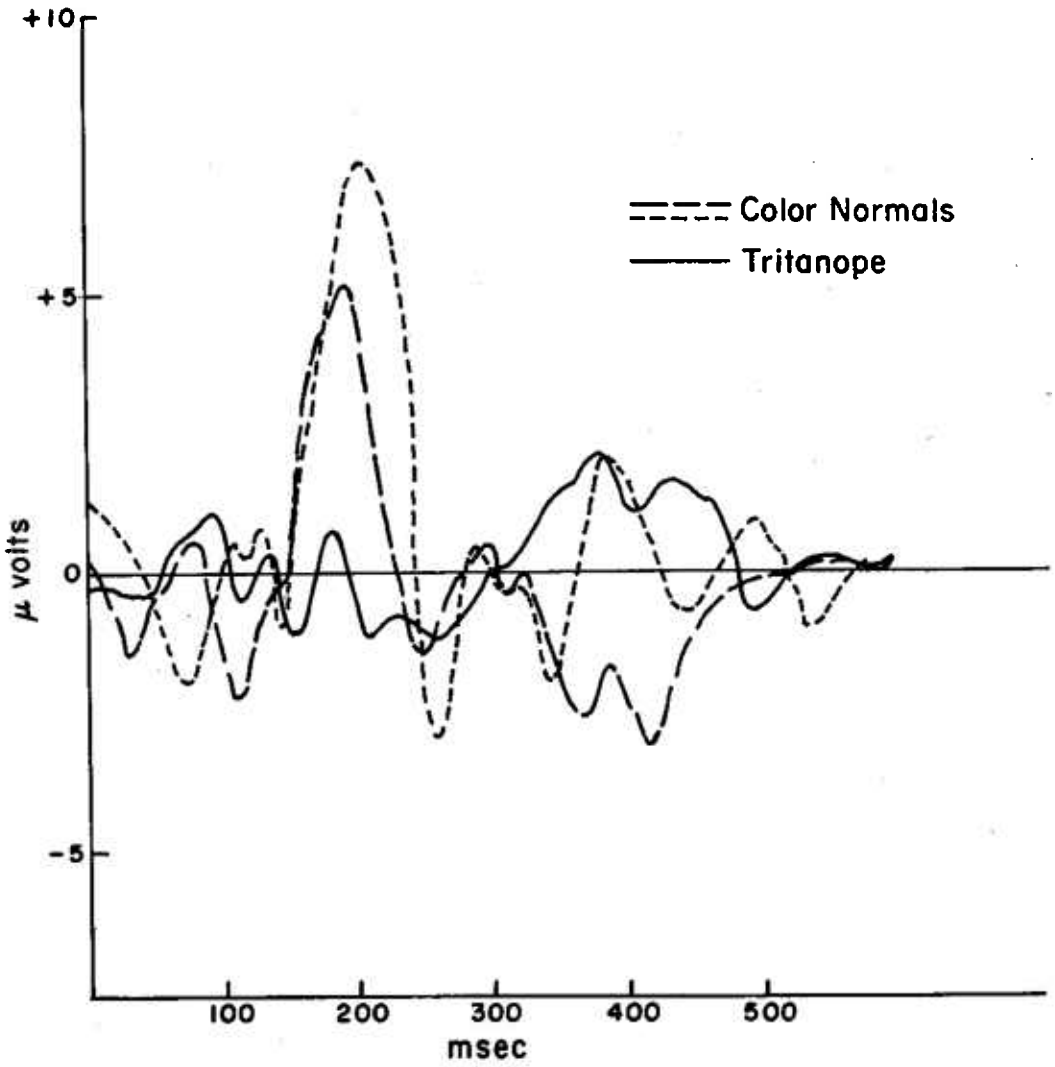


Fig. 14. Pattern responses for two color normals and one tritanope on the tritanope's hue target.

which of the two variables is being tapped in a given pattern response. An even better method would be to form the hue patterns from lights of variable luminance; the luminance of one of the hues could then be adjusted up and down to determine if the pattern response would disappear. For color normals, of course, no luminance adjustment would eliminate the pattern response to hue.

Two other results of this investigation should be emphasized; the first is the dependence of the latency of the pattern response on contrast. The

relation between latency and luminance contrast should probably not be surprising in view of the clear-cut relations found between latency of the VER and luminance[9] and between luminance contrast and amplitude of the VER.[10] However, the longer latency of hue-contrast pattern responses, compared to luminance-contrast pattern responses, was unexpected, since the targets were constructed to be of equal "subjective" contrast, whether the parameter was hue or luminance. This dependence might result because hue processing is based on inhibitory connections, whereas brightness processing may be based on excitatory.

Finally, there is the fact that the pattern response was independent of whether the recording was monopolar or bipolar. This is yet another indication of the power of pattern in eliciting VERs. The dependence of the evoked response on pattern is one of the most universal findings in the literature.[2] The result of this investigation implies that the source of the pattern response is confined to a small area in the primary visual cortex, since its amplitude does not vary when the reference electrode is 5 cm above it or placed on the other ear.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY, Naval Submarine Medical Center	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

THE VISUAL EVOKED CORTICAL POTENTIAL AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: (3) THE RESPONSE TO PATTERN AND COLOR

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim report

5. AUTHOR(S) (First name, middle initial, last name)

Jo Ann S. Kinney and Christine L. McKay

6. REPORT DATE 19 March 1974	7a. TOTAL NO. OF PAGES 19	7b. NO. OF REFS 22
8a. CONTRACT OR GRANT NO. b. PROJECT NO. M4305.08-3001DAC9.09 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NSMRL Report No. 778 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Submarine Medical Center Box 600, Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

Previous research has shown that it is possible to isolate a response to pattern from the visual evoked cortical potential. This study investigated the optimum conditions for yielding a pattern response and then applied the pattern response to a test of color vision. The results showed that individuals with normal color vision will give a response to pattern when the pattern is formed of either hue differences or luminance differences. Color defective individuals, however, respond only to luminance differences and not to hue differences that they cannot discriminate. The technique thus can be used as an objective measure of color vision.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0102-014-6600

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Visual evoked responses						
Color defects						
Tests of color blindness						